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Soundscapes

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LONG-TERM GOALS

To develop and validate a regional and global nowcast capability for ocean noise. The ambient noise field is, of course, a key part of the marine mammal habitat, and in turn can inform regulatory decisions by conservationists.

OBJECTIVES

Eventually this system will be coupled to global oceanographic models to provide hindcasts, nowcasts, and forecasts of the time-evolving soundscape. In terms of the types of sound sources, we will focus initially on commercial shipping and seismic exploration. As the research evolves we will gradually expand the capability to include many other types of sources.

APPROACH

The research has two principle thrusts: 1) the modeling of the soundscape, and 2) verification using datasets that have been collected around the Pacific and Atlantic Ocean basin. In terms of the modeling, we have begun with adiabatic normal modes (KRAKEN3D); in the adiabatic approximation, one assumes that the sound energy in any particular mode stays in that mode as the sound propagates radially from the source. This particular approach is extremely efficient. Longer term we will be including other models such as BELLHOP3D that can include mode coupling and 3D refractive effects.

Regardless of the model type, we first pre-calculate the transmission loss (TL) for a grid of hypothetical sources covering the globe. We then compute the noise level (NL) by convolving this TL data with a source level (SL) density. This two stage approach allows us to rapidly produce updated soundscapes as the SL density changes due to different source types or to temporal variations.

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WORK COMPLETED

This work commenced in the fourth quarter of GFY2012; however, we are jumping off preliminary work done under a previous program focusing on the U.S. EEZ. As a result we have been able to rapidly complete a preliminary *global* soundscape due to merchant shipping at a 1-degree latitude/longitude grid spacing. We have also created a detailed soundscape for the Gulf of Mexico at a 0.1 by 0.1 degree spacing.

This sort of calculation involves quite a few steps, particularly when we include different sources such as multiple ship-types, air-gun arrays, pile drivers, and sonar. As a means of ensuring the calculations are correct, we have re-structured the algorithms so that all source types are first mapped into a SL density. This SL density represents the power spectral density in a 1-Hz band for a nominal 1-m source depth and per unit area (dB/Hz/m^2). These SL density maps are very informative in themselves to get a general sense of the energy the source is putting into the water column. As mentioned above, the final stage is then to convolve that SL distribution with the channel response to bring in the propagation effects.

Finally, we have also begun working with various collaborators to do model/data comparisons. Our first results done for a variety of sites in the Pacific (work with Rex Andrew of APL-UW) showed excellent agreement. We will discuss below also some further work with Megan McKenna around the Santa Barbara Channel.

RESULTS

A key issue in this sort of calculation is to find the environmental data needed for the entire globe. For the ocean sound speed, we used the World Ocean Atlas (WOA) annual average, already on a 1-degree grid. For bathymetry, we converted the SRTM-30 bathymetry (http://topex.ucsd.edu/WWW_html/srtm30_plus.html) to a 1-degree lat/lon grid. For bottom properties, we combined the NOAA sediment thickness database, the unclassified version of the Navy's BST (Bottom Sediment Type), and dbSeabed instaar.colorado.edu/~jenkinsc/dbseabed/). Examples of some of these environmental inputs are shown in Figs 1-3.

The next key ingredient is the source level data. For global shipping, we used the global merchant shipping based on the VOS (Volunteer Observation System) from Halpern et al (2009) and supplied to us by Carrie Kappel of the Center for Marine Assessment and Planning, UCSB (personal communication, 2012). Approximately 10% of the global fleet provides their ship positions to VOS. To agree with the source levels of the modern global fleet, the VOS ships were calculated to consist of about 82% ANDES type "Merchant Vessel" and 18% "Large Tanker". The global shipping data is shown in Fig. 4 where it is presented in terms of km of track per 10x10 km square. This information is reprocessed into SL density maps as described above.

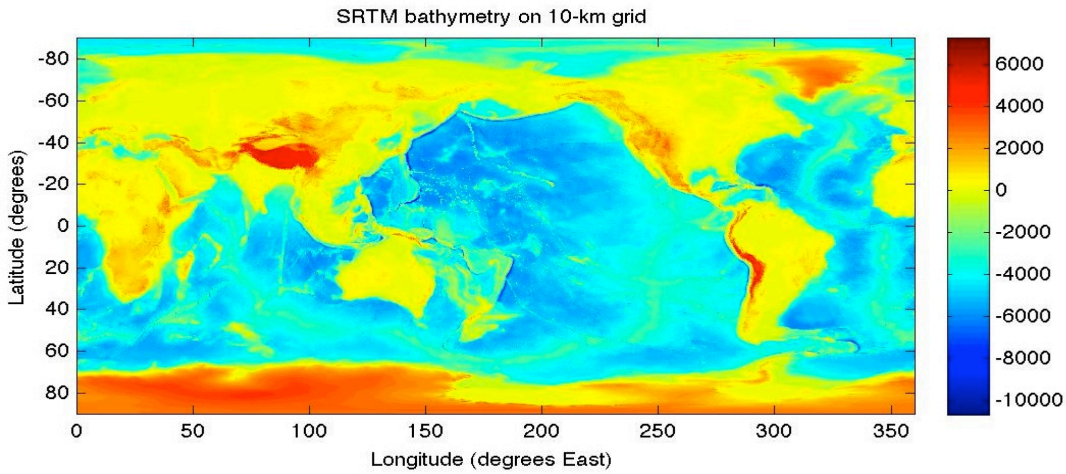


Figure 1. *SRTM-30 bathymetry, here shown on an approximately 10x10km grid.*

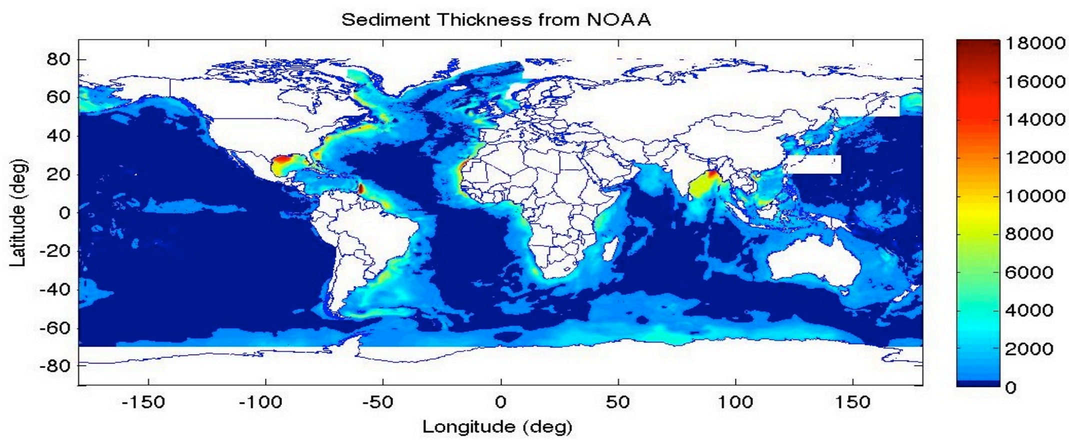


Figure 2. *Sediment thickness from NOAA.*

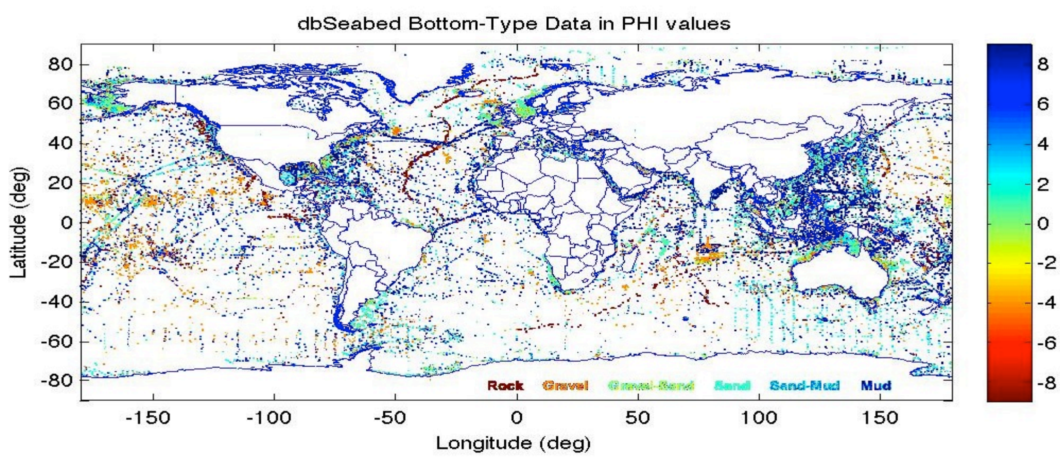


Figure 3. *dbSeabed information for grain-size, shown in phi units.*

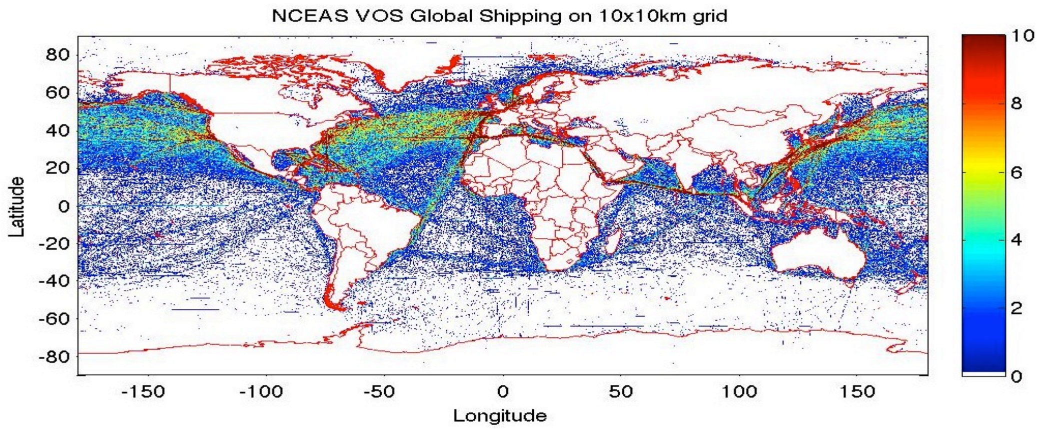


Figure 4. *Global merchant shipping based on the VOS (Volunteer Observation System) from Halpern et al (2009).*

The left panels of Fig. 5 show the resulting SL density maps for 50 Hz (upper left) and 800 Hz (lower left). Note that because the minimum number of VOS ships in a cell (kilometers of ship tracks per km^2) is 1; the minimum SL density (ρ_{SL}) is 79 dB for "Merchant Vessels" at 50 Hz, and so on. This caused the lack of colors yellow through dark blue in the SL density maps shown in the upper left panel and the lack of the color dark blue in the lower left panel of Fig. 5.

Finally we convolve the SL density map with the transmission loss data to obtain the soundscapes shown in the right panels of Fig. 5.

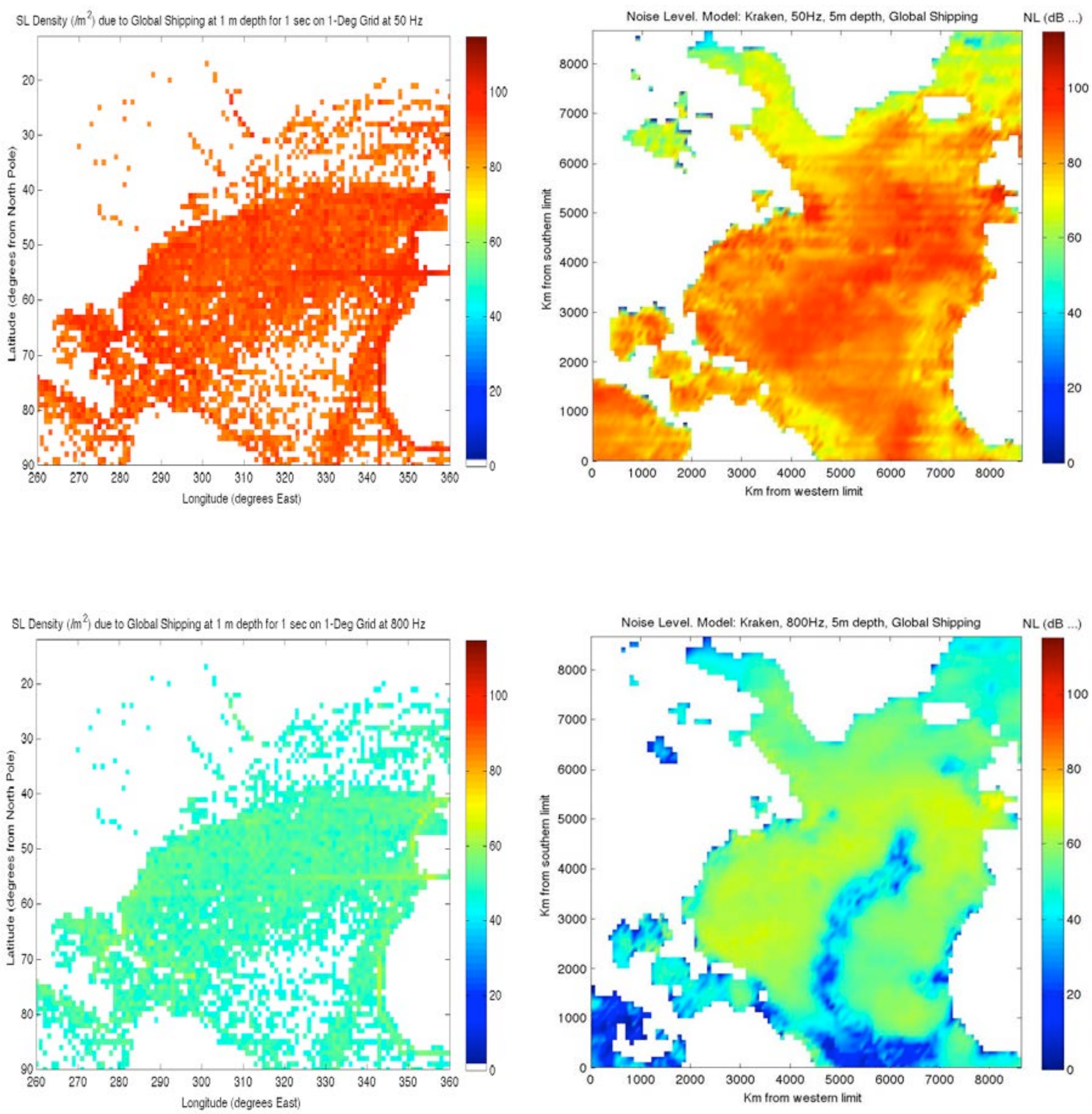


Figure 5. *Source level density (left panels) and modeled noise level at 5 m depth (right panels) due to merchant shipping in the northern Atlantic ocean for the year 2006. Upper panels are for 50 Hz and lower panels for 800 Hz. Note that source level density is not affected by bathymetry such as the mid-Atlantic Rise.*

We have now calculated truly global soundscapes for 1-Hz bands at 50, 100, 200, 400, and 800 Hz, and depths 5, 15, 30, 200, 500 and 1000 m. Figure 6 shows an example global soundscape for a 200 Hz frequency as rendered in Google Earth.

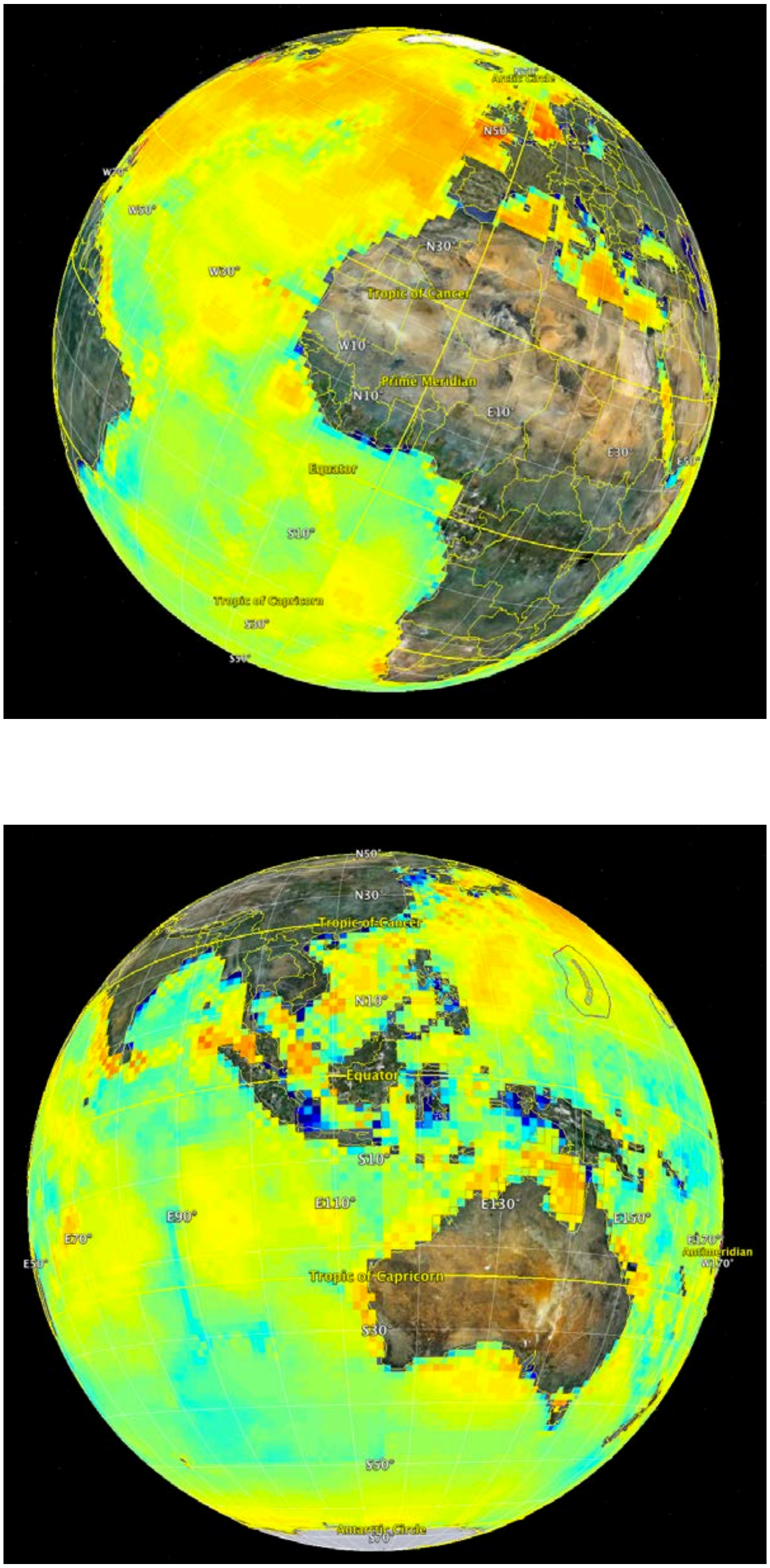


Figure 6. *Modeled noise soundscape due to merchant shipping for the year 2006. The frequency is 200 Hz and the receiver depth is 30 m.*

An obvious question is: how can one validate the model results? In collaboration with Rex Andrew (APL-UW) we have overlain results from a large number of hydrophone arrays in the N. Pacific and the agreement is quite good (typically deviating by less than 5 dB from annual averages). Considering the uncertainties in shipping densities, source levels, and environmental information this is surprisingly good.

Separately we have just begun to work with data collected by Megan McKenna for her Ph.D. dissertation at Scripps Institute of Oceanography. She had several hydrophones deployed in the Santa Barbara channel, and was simultaneously able to get real-time AIS data. As figure 7 shows, proper SLs are essential. So far we have made a comparison between actual ship SLs and an arbitrarily-assigned constant SL of 150 dB for all ships in the area. Next we will compare our VOS SL estimates to the actual ship SL's in the Santa Barbara Channel. If the agreement is not good, we will adjust the SL's and estimated percentages of modern commercial ship types as input to our model. Figure 8 shows the beginnings of an improved data-set of modern ship-types and SL's from McKenna et al (2012).

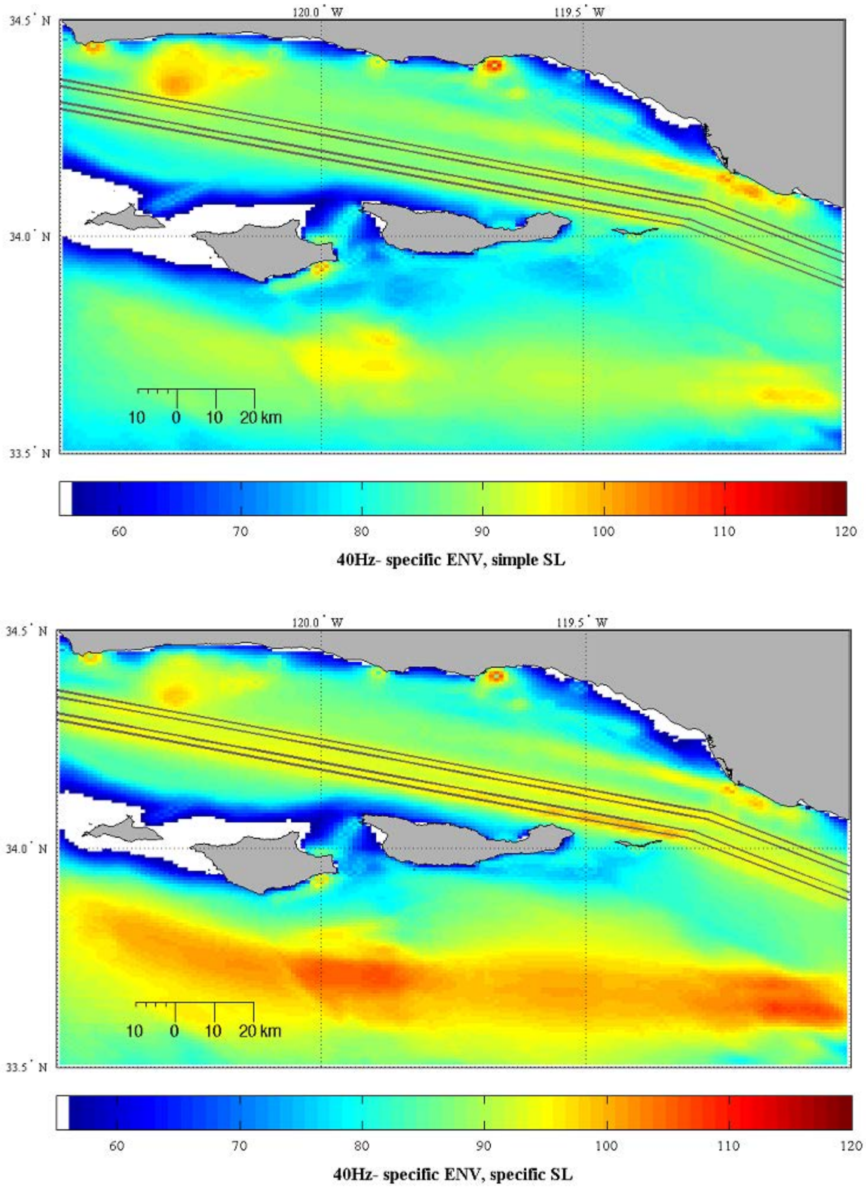
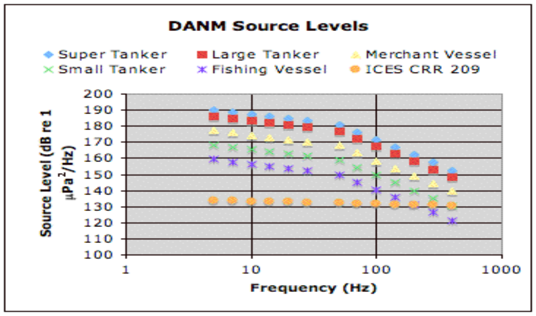


Figure 7. *Modeled noise level in the Santa Barbara channel due to artificially assigned source level of 150 dB for all ships (top) and more realistic source level based on ship classification and length (bottom) .*



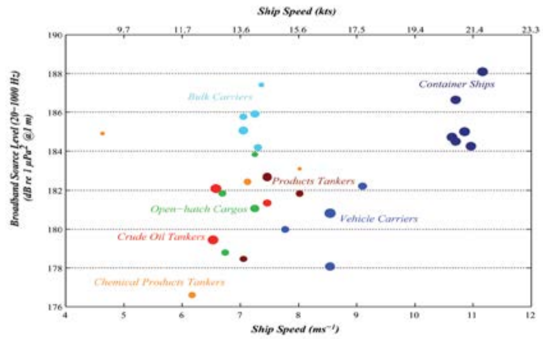


Figure 8. *Source levels for idealized ship types from DANM/ANDES for ships active during the early 1980's (left), and source levels of various modern ships collected by McKenna et al (2012) (right).*

IMPACT/APPLICATIONS

The importance of this work is that it provides information on the ambient noise field, which is a key part of the marine mammal habitat, and in turn can inform regulatory decisions by conservationists. For instance, one may assess the value of ship quieting and the role of acidification. In addition, the ambient noise provides the background field against which new sound sources such as pile drivers are heard. It also facilitates the studies of masking effects on marine mammals.

RELATED PROJECTS

The initial work on noise modeling was done as a part of the NOAA Underwater Sound Field Mapping Working Group which has been concerned specifically with the U.S. EEZ.